A COMPARISON OF
LINE-SCAN AND PHOTOGRAPHIC IMAGES
FOR TARGET IDENTIFICATION

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ACKNOWLEDGMENTS

We sincerely thank the photointerpreters
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INTRODUCTION

There have been several studies of the effects of photo-
graphic ground resolution on the intelligence output of
photointerpreters (PIs) and intelligence analysts. There
have been fewer studies of the effects of line-scan imagery
on intelligence output. The purpose of the study reported
here was to make an initial determination of the relation be-
tween line-scan and photographic imagery in terms of PI
target identification performance. The relations between the
two types of imagery should be determined so that the de-
signers of line-scan systems can use the results of the re-
search on the effects photographic ground resolution has on
the performance of different PI and analyst tasks.

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recently completed an experimental study to determine the
informative value of static line-scan images as a function of
two variables: (1) number of scans per target and (2)
signal-to-noise ratio.

Photographs were taken of 20 models: 10 tanks and 10
miscellaneous vehicles, such as trucks and armored cars.
The photographs were transformed into line-scan transparencies
so that there were either 16, 32, or 48 scans per target.
Gaussian noise was added to the transparencies producing
signal-to-noise ratios of 3, 5, 10, 20, and 30 for each of
the three numbers of scans. There was also a noiseless image
for each of the three numbers of scans.

The subjects were 54 college students. Each subject
was assigned randomly to one of six groups, and each group

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viewed three transparencies that contained the same amount
of noise but a different number of scans per target. The
targets were in different positions in the three transparen-
cies. The models were mounted on a board in front of the
subjects, and their task was to match each target image with
each target model, a task similar to matching a target image
with the target as portrayed in a PI key.

In the analysis, the tanks were treated as one class
of targets and the miscellaneous vehicles were treated as
another. Matching a target image with the target model was
considered a correct "identification," and the percentage
of correct identifications was computed for each target
class and each experimental condition. The results of the
study were reported in [   ] The   STAT
informative value of line-scan images as a function of sig-
nal and noise characteristics (white, Gaussian, signal-
independent noise) [   ] March,   STAT
1969. ~~Some of the data are presented in the "Results" sec-~~
~~tion of this report.~~

METHOD

The method used in the study reported here was similar
to that used by [   ] However, PIs not   STAT
only viewed the line-scan imagery used in the previous study,
they also viewed conventional photographic transparencies of
the same targets at five different ground resolutions.

Their task was to match the line-scan target images
and conventional photographic target images with the target
models. The percentage of correct identifications was com-
puted both as a function of number of scans per target and
signal-to-noise ratio in the line-scan images, and as a
function of photographic ground resolution.

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Preparation of the Images

Following are descriptions of how the line-scan and photographic transparent images were prepared [ ] The STAT
line-scan images used in the study reported here were the same ones used [   ] and a more com- STAT
plete description of the image preparation is given in their report.

The line-scan images. The model targets were placed on a uniform background and the position of each was random. They were placed so that all of them extended an equal distance in the direction perpendicular to the scan direction. This was done so that each image would be formed by approximately the same number of scan lines.

A diffuse light source was used to simulate the illumination of the sky, and another point light source was used to simulate the sun at 50° above the horizon.

Three different random arrangements of the models were photographed with Kodak High Definition Aerial Film, Type 3404, in a 35mm camera. Each photograph was enlarged so that the subsequent conversion into line-scan images would result in 16, 32, and 48 scans per target.

The enlarged photographs were transformed into line-scan images using the [ ] Line-Scan Image Generator[1] and STAT
associated Digital Tape Memory System[2]. The sampling and reconstruction spots were identical and circularly symmetrical; they had Gaussian intensity distributions with half-amplitude diameters of 0.55mm. The scan spacing was 0.55mm.

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[1] Scott, F. A line-scan image generator, *Photo Sci. & Eng.*, Vol. II, 5, 1967.

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The photographs were sampled at intervals of 0.55mm, the half-amplitude of the spot diameter. The sampled transmittance was quantized into 12 bits (virtually analog imagery) and recorded digitally on tape.

Noise was added to the quantized transmittance producing an output image with the desired noise characteristics. The noise elements were generated using a random-number-generator subroutine on an SDS 930 computer.

The noise had a Gaussian transmittance distribution, and different standard deviations of the distribution were used to produce signal-to-noise ratios of 3, 5, 10, and 20[3]. The signal-to-noise ratio was defined as the ratio of the standard deviation of the signal to the standard deviation of the noise, *in transmission space.*

Fourteen line-scan image transparencies were produced with the characteristics shown in Table 1. Each cell in the table represents a line-scan transparency characterized by the column and row values. (Note that a transparency was not made to represent 48 scans and a signal-to-noise ratio of 20, because it would have been almost identical to the noiseless imagery.)

Each transparency contained the images of the 20 model targets. The position of the vehicles was the same in all transparencies in each row in the table but differed from one row to the next.

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[3]A signal-to-noise ratio of 30 was also used in the study. It was not used in the study reported here because identification performance with it was not significantly different from performance with noiseless line-scan imagery.

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TABLE 1

CHARACTERISTICS OF THE LINE-SCAN TRANSPARENCIES

NUMBER OF SCANS PER TARGET	SIGNAL-TO-NOISE RATIO				
	3	5	10	20	∞ (Noiseless)
16					
32					
48				*	

*A transparency was not made to represent this cell.

The photographic images. The photographic images used in the study were made by ⬚ from the original negative used in making the 48 scan, line-scan images[4]. The method used is described in detail in Appendix A, which is a copy of the ⬚ report submitted to ⬚ with the photographs.

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The ground resolution of the five photographs was determined from the average of the three-bar target readings made by three photographic scientists. The ground resolutions were: ⬚
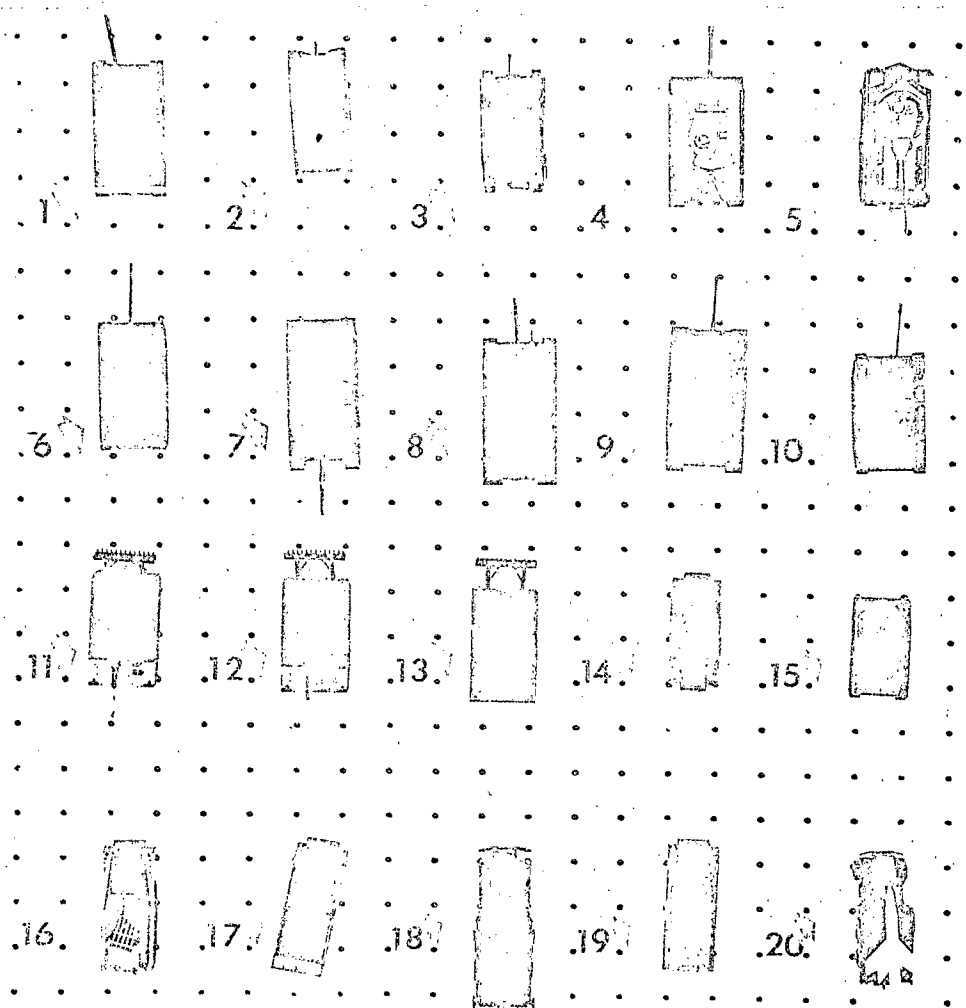
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The Targets

Figure 1 is a photograph of the models used as targets in the study.

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[4]After they were prepared, the photographs were cut and the targets rearranged so that their position would not be the same as their position in the 48 scan, line-scan images.

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1. Russian T-54 Tank
2. U. S. Medium Sherman M4, A4 Tank
3. German Tank IV/H
4. German Tiger (1) Tank
5. Joe Stalin III Tank
6. U. S. Medium M-60 Tank
7. British Centruion Tank
8. U. S. Medium Patton M-47 Tank
9. French Medium Tank AMX30
10. U. S. Light "Walker Bulldog" M-41 Tank
11. Tank Recovery Vehicle T-119
12. Tank Recovery Vehicle T-120 (1)
13. U. S. T-120 Tank Recovery Vehicle
14. German 234/1 Armored Car
15. U. S. M-106 Mortar Carrier
16. German Half Track Rocket Carrier
17. Half Track - Munition Carrier
18. U. S. M-62, 5-Ton Wrecker Truck
19. German Sound Detector
20. U. S. La-Cross Missile XM 4 E2

Figure 1. The model targets.

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TABLE 2

EXPERIMENTAL DESIGN

NUMBER OF SCANS PER TARGET	SIGNAL-TO-NOISE RATIO				
	3	5	10	20	∞
16	G1	G5	G3	G4	G5
32	G1	G2	G3	G4	G5
48	G1	G2	G3	*	G5

*This cell was not represented in the study.

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Subjects

The subjects were 50 professional PIs. Their mean experience was 5.3 years. Eight of them were from IAS, 24 from IEG, 8 from SPAD, and 10 from _____ STAT Nineteen of the subjects specialized in ground order-of-battle (GOB) targets.

Experimental Design

Each subject was randomly assigned to one of five groups with the restriction that about the same number of GOB specialists be in each group of 10: the 19 specialists were distributed 4, 4, 4, 4, 3 in the five groups.

The subjects in Groups 1, 2, 3, and 5 viewed three line-scan transparencies and a photographic transparency. The subjects in Group 4 viewed two line-scan transparencies

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and a photographic transparency. All subjects viewed line-
scan transparencies that differed in the number of scans per
vehicle, but had the same signal-to-noise ratio. Table 2
shows the experimental design.

Procedure

Each subject was seated at a light-table and given a
loop and a microscope with which to view the imagery. A set
of the 20 model vehicles arrayed in 4 x 5 matrix on a board
was placed in convenient view of the subjects. Each model
was identified by a number ranging from 1 to 20.

The purpose of the experiment and rules for the task
were explained to the subjects. The rules were as follows:

1. Match the images to the models in the order
   they appear in the transparency proceeding
   from the upper left-hand corner of the trans-
   parency to the lower right. Do not skip any
   images; respond to them in order.

2. Match each image to a model and write the num-
   ber of the model on your answer sheet.

3. Consider each match independently of all other
   matches. You may match the same model to more
   than one image.

4. Your initial selection is considered as final;
   do not change your answer unless you get per-
   mission to do so.

5. Use any magnification you wish.

6. Work at your own pace and take breaks when you
   wish.

The subjects were given the appropriate transparencies
in the predetermined orders. Each subject completed the
matching task for a given transparency before the next one
was given to him.

The average time taken to complete the task was about
one-and-one-half hours.

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RESULTS

The results of the study are shown in Table 3 and Figure 2 for the tank targets and in Table 4 and Figure 3 for the miscellaneous vehicle targets.

Some of the results are immediately apparent. The tanks were more difficult to identify correctly than the miscellaneous targets in both the photographic and the line-scan images: distinguishing among the tanks is simply a more demanding perceptual task than distinguishing among the miscellaneous targets.

For both classes of targets, higher per cent identification measures were obtained with larger signal-to-noise ratios. For the tank targets, 48 scans per target resulted in higher per cent identification measures than 32, and 32 resulted in higher measures than 16. For the miscellaneous targets, 48 and 32 scans per target were better than 16 but there was little difference between 48 and 32.

No effort has been made to smooth the functions shown in Figures 2 and 3 because additional work must be done to obtain the required reliability. Implied in that statement are more targets, more imagery, and more experimental subjects.

Table 5 shows a few of the equivalences in terms of per cent correct identifications of tank targets between photographic ground resolution and line-scan image characteristics. The table was prepared to illustrate how data from studies like the one reported here can be used to determine the requirements and specifications of a line-scan system.

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TABLE 3

PER CENT CORRECT IDENTIFICATION OF TANKS

NUMBER OF SCANS PER TARGET	SIGNAL-TO-NOISE RATIO				
	3	5	10	20	∞
16	18	20	27	32	56
32	31	38	52	60	83
48	32	43	75	*	98

*This cell was not represented in the study.
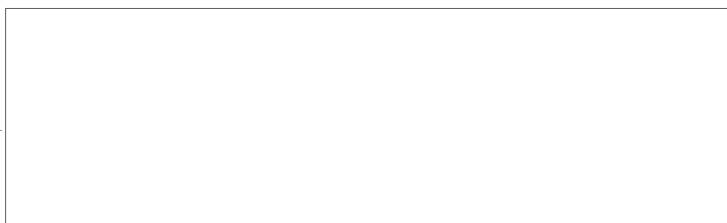
TABLE 4

PER CENT CORRECT IDENTIFICATION OF MISCELLANEOUS TARGETS

NUMBER OF SCANS PER TARGET	SIGNAL-TO-NOISE RATIO				
	3	5	10	20	∞
16	43	44	50	64	83
32	65	59	85	95	100
48	74	79	87	*	98

*This cell was not represented in the study.
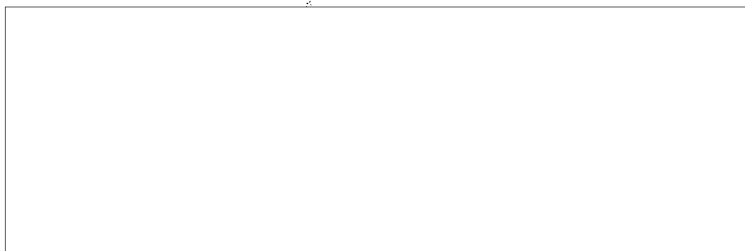
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TABLE 5

EQUIVALENCES IN TERMS OF TARGET IDENTIFICATION
PERFORMANCE AMONG LINE-SCAN AND PHOTOGRAPHIC IMAGES
(Tank Targets Only)

IMAGE SPECIFICATIONS

PER CENT CORRECT IDENTIFICATIONS	16 SCANS/ TARGET	32 SCANS/ TARGET	48 SCANS/ TARGET	
50	39.5 S/N*	9.5 S/N	6.0 S/N	
60	**	20 S/N	7.6 S/N	
70	**	31 S/N	9.3 S/N	
80	**	42 S/N	18.0 S/N	
90	**	**	32.1 S/N	
98	**	**	40.0 S/N	

* Signal-to-noise ratio
**The imagery specified in these cells of the table will
  not yield the percent correct identifications indicated.

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DISCUSSION

The study reported here was the first effort designed
to determine the relation between line-scan and photographic
imagery. The usefulness of the results is limited because
the samples of targets and subjects were small. However,
an important first step has been made, and because it is
obvious line-scan systems are going to be developed, add-
itional steps must be made so that both collection and ex-
ploitation systems can be properly designed.

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APPENDIX A

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VEHICLE GEM SET

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A set of positive GEM photographs was generated by photographing a negative original with controlled degradation in a 1:1 optical system. The degradations were achieved by defocusing the optical system. The resulting GEMs frequency spectra are shown in Figure 2. The frequency spectra of the GEMs was measured by scanning edges in the scene with a microdensitometer and processing the data with a form of edge gradient analysis. A GEM master negative was not required as the original negative supplied had a gamma of 1.0.

The choice of an optical system for the generation of the GEMs was based on the ease this method affords for controlled image degradation and by the time and cost limits imposed on this program. A 1:1 camera system was set up on an optical bench and consisted of a 105mm Schneider Componon lens, target holder and film back. Defocusing was achieved by movement of the film back away from the target holder by a micrometer stage adjustment. The original negative's frequency spectra did not contain high frequency information as is shown in Figure 1. This MTF curve was determined by scanning several edges throughout the original negative frame format and selecting a transfer function that was the approximate center of the data spread. Thus phase shifts caused by defocusing was not a problem, due to the nature of the original scene. Tri-bar resolution was used to determine the positions of the film back which gave resolutions of approximately 1/2, 1/4, 1/8, and 1/16 of that obtained at the prime focal position. These positions were then used to photograph the scenes, along with a target array which consisted of an edge, high and low contrast tri-bar targets. The addition of these targets was made necessary by the large amounts of defocus used. Measurements of edges within the scene could not be made for cases of low resolution due to the large area required to properly measure the edges. The density differences of the edge and background in the target array were selected to nearly match the density

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differences in the scene. Listed in Table 1 are the
density values for the GEMs and the reference target array.
Density measurements were made on vehicles in the four
corners and in the center of the scene. The results of
measurements made on the test target control edges appear
in Figure 2. Traces of reference edges contained in the
scenes for which it was possible to measure the edges (num-
ber 0, 1, and 2) are given in Figure 3. The image for the
remaining GEMs could not be traced due to problem of the
scan length required. The data given in both these figures
is uncorrected for the microdensitometer optics and slit,
since this would only affect the level of the curves not
their relative scaling to each other.

The final GEM images were made on Kodak 5235 duplicat-
ing film process in D-76 at 68° F. to give a gamma of 1.0.
Exposures were adjusted so that the final scene densities
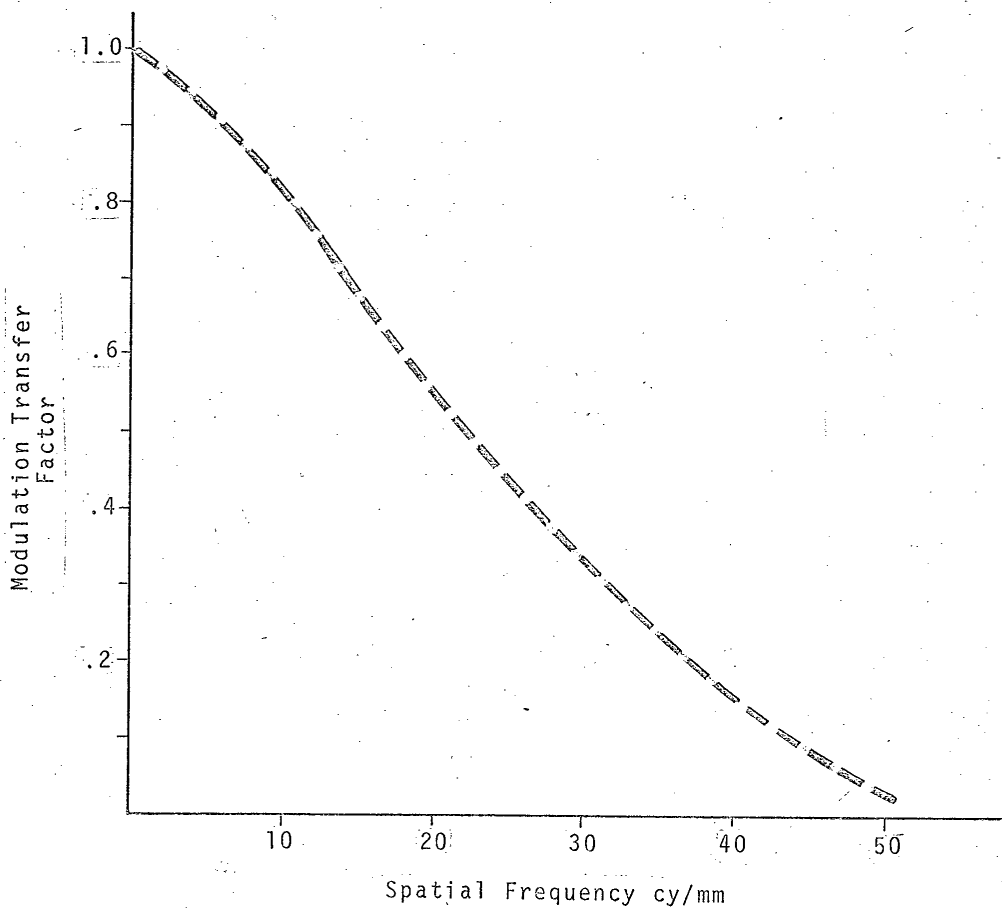remained approximately the same throughout the entire GEM
set.

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Figure 1.   Selected Nominal Scene Transfer
Function for GEM Original Negative
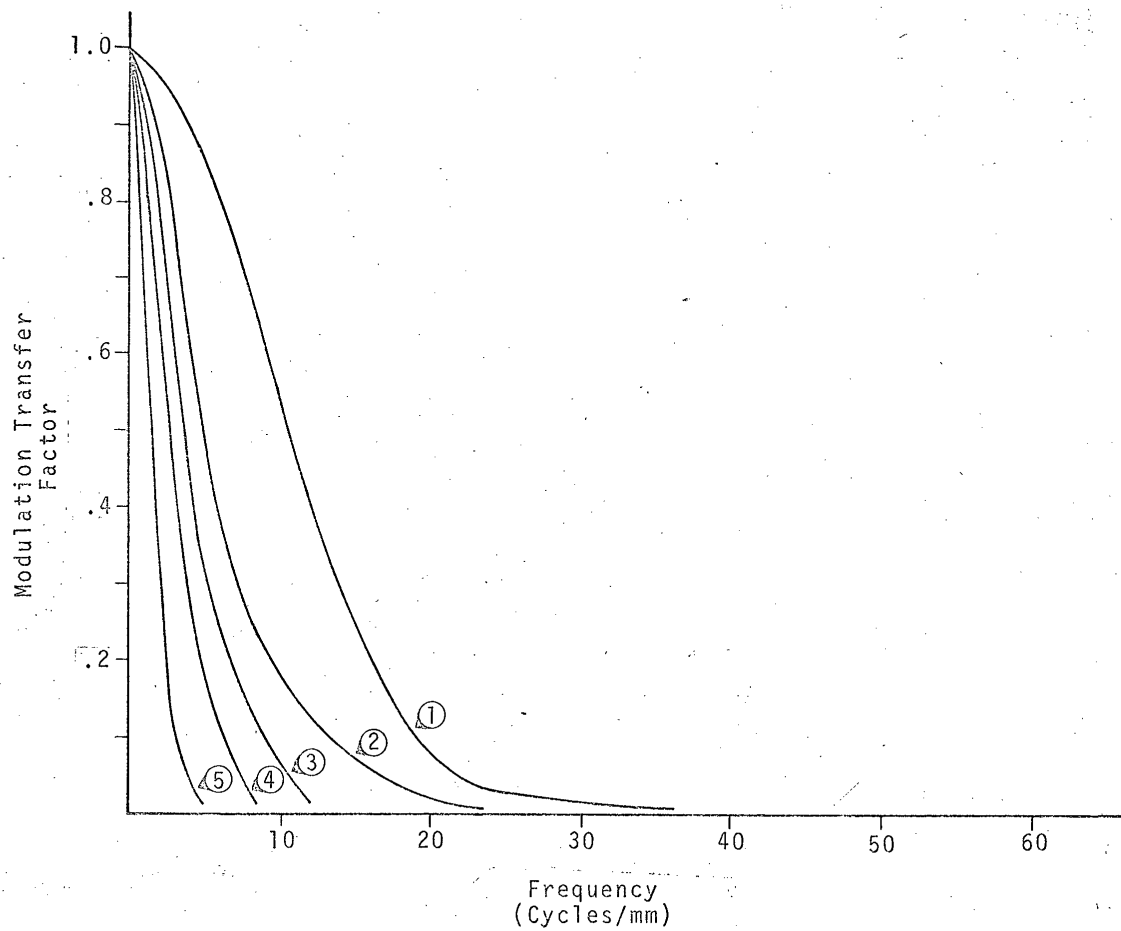
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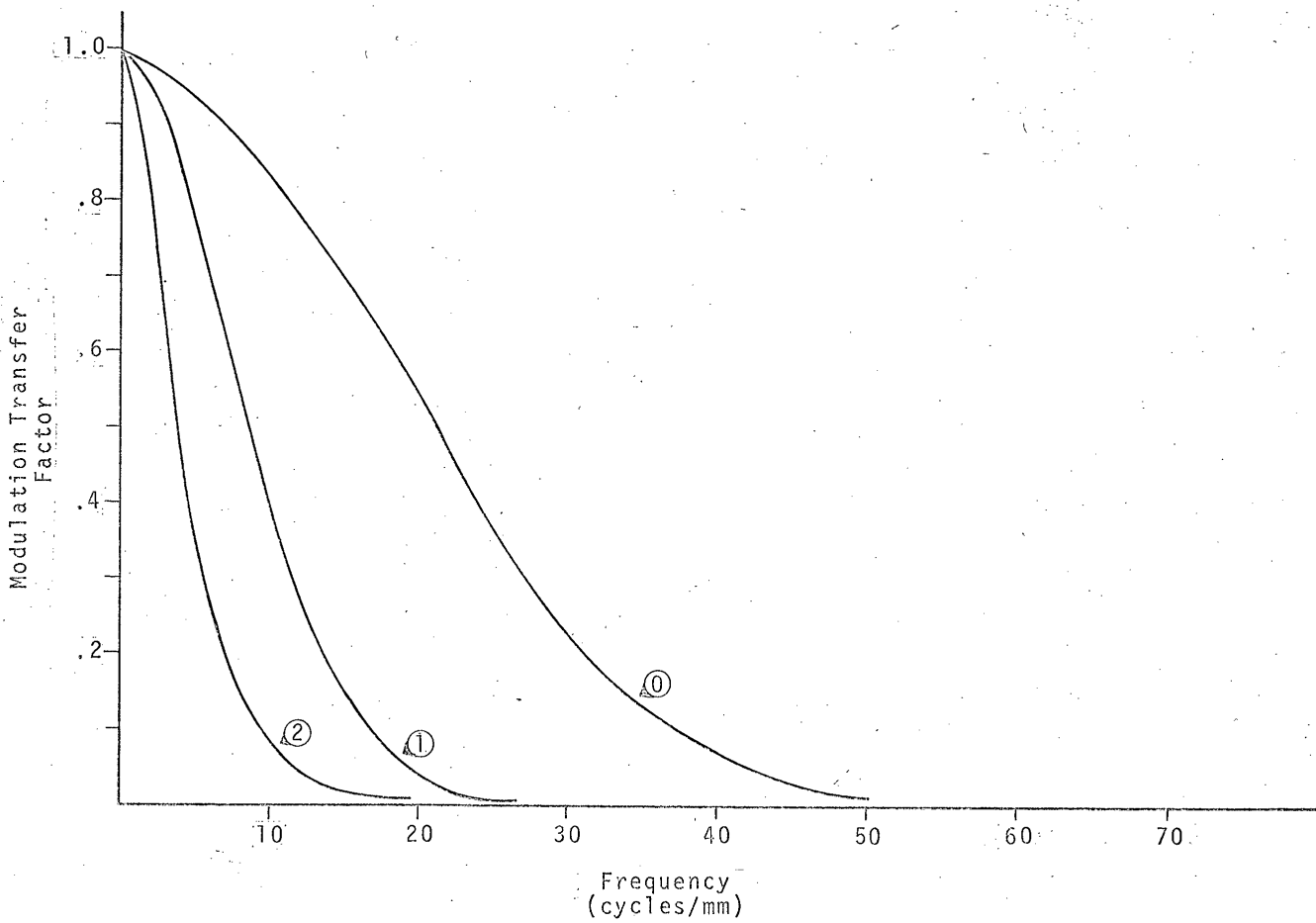Figure 2. Target Edge Frequency Spectrum

Figure 3.   GEM Frequency Spectrum

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TABLE 1

DENSITY MEASUREMENTS ON GEM AND TARGET ARRAY

Original Target Array

	High Contrast	Edge Target	Low Contrast
D-Max	2.58	1.07	.49
D-Min	.04	.04	.04
Density Difference	2.54	1.03	.45

Target Array High Contrast

	GEM # 1	2	3	4	5
D-Max	1.42	1.38	1.40	1.36	1.40
D-Min	.09	.09	.09	.09	.08
Density Difference	1.33	1.29	1.31	1.27	1.32

Target Array Low Contrast

	GEM # 1	2	3	4	5
D-Max	1.34	1.31	1.35	1.32	1.34
D-Min	.78	.74	.79	.78	.77
Density Difference	.56	.57	.56	.54	.57

Edge Target Array

	GEM # 1	2	3	4	5
D-Max	1.34	1.32	1.33	1.41	1.35
D-Min	.37	.36	.36	.36	.36
Density Difference	.97	.96	.97	1.05	.99

GEM Array

GEM #	Density of Background	Density of Corner Vehicles				Density of Center Vehicle
1	.27	1.08	1.27	1.10	1.31	1.26
2	.25	1.04	1.25	1.14	1.29	1.26
3	.24	1.06	1.28	1.13	1.32	1.23
4	.25	1.03	1.28	1.15	1.33	1.28
5	.28	1.10	1.22	1.19	1.38	1.25

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